News and Reminders

Homework 2 is due Monday, Sep. 30

- For question 1 you will also be graded on the quality of your figures: appropriate and legible titles and axis labels, legible tickmark labels, use of colors if needed to distinguish between different variables plotted on the same figure, legibility of plots themselves (e.g. point size not too large or small, etc.)
  - PHYS 480 students: don't be afraid to attempt question 1!
  - for question 1, use the whfast integrator; to speed up, try increasing dt rather than decreasing the total time.
- Please send JC 3 and 4 questions typed, by email.

Next quiz - Wednesday, Oct. 2

Mid-semester proposal due dates:

- To submit or not to submit: Today!
- Abstract due: Monday, October 7
- Proposal due: Monday, October 28

$$I_\nu = C \cdot e^{-\tau_\nu}$$
$$= I_\nu(0) e^{-\tau_\nu}$$

($I_\nu(0)$ ← initial intensity)

$\tau_\nu \leq 1$: optically thin

$\tau_\nu \gg 1$: optically thick

at $\tau = 1$, $I(0)$ has decreased by a factor of e

Optical depth varies with wavelength:

Cosmic/solar X-Rays, γ-Rays, UV are absorbed high in Earth's atmosphere by nitrogen and oxygen (ozone for UV)

Much of optical, IR and radio light passes through.

What about emission in the medium?

It gets added to the initial radiation:

$$\frac{dI_\nu}{ds} = j_\nu \rho - \alpha_\nu \rho I_\nu$$

j_ν ← mass emission coefficient (W/(kg · Hz · sr))

now define source function:

$$S_\nu = \frac{j_\nu}{\alpha_\nu}$$

measure of how photons are removed and replaced by new photons by the material the light is passing through

$$\Rightarrow \boxed{\frac{dI_\nu}{d\tau_\nu} = S_\nu - I_\nu}$$ ⇐ radiative transfer equation

This is a linear first order differential equation. General solution is:

$$I_\nu(\tau_\nu) = I_\nu(0)e^{-\tau_\nu} + \int_0^{\tau_\nu} S_\nu(\tau_\nu')e^{-(\tau_\nu-\tau_\nu')}d\tau_\nu'$$

S_ν usually messy and can depend on I_ν, but:

Case 0: For a uniform medium (S_ν not dependent on τ_ν):

$$I_\nu(\tau_\nu) = I_\nu(0)e^{-\tau_\nu} + S_\nu(1-e^{-\tau_\nu})$$

Class: what happens at $\tau \ll 1$? $\tau \gg 1$? does it make sense?

Case 1: non-emitting medium

$$j_\nu = 0 \Rightarrow S_\nu = 0 \Rightarrow \boxed{I_\nu(\tau_\nu) = I_\nu(0)e^{-\tau_\nu}}$$

Lambert's exponential absorption law (or Beer's law)

Case 2: Local thermal equilibrium (LTE) and no scattering (i.e. $\sigma_\nu = 0$); energy emitted = energy absorbed

$\alpha_\nu = K_\nu$

so: $j_\nu = K_\nu B_\nu(T)$ (radiation in TE)

$\tau \gg 1$: $I_\nu = S_\nu = B_\nu$ (often assumed for stars and planets)

$0 < \tau \ll 1$: $I_\nu = I_\nu(0) + S_\nu(1-(1-\tau_\nu))$

$= I_\nu(0) + \tau_\nu B_\nu(T)$

still blackbody but scaled way down

Pressure Scale Height:

distance over which pressure decreases by a factor of e;

need to assume hydrostatic equilibrium (good to first-order for most atmospheres)

$$H(z) = \frac{K\,T(z)}{g_p(z)\,\mu_a\,m_{amu}} = \frac{K\,T(z)}{g_p(z)\,\bar{m}}$$

μ_a: mean molecular weight

m_{amu}: atomic mass unit

$\bar{m}$: mean mass of a molecule

H varies with altitude!

Class: at a given T, do giant or terrestrial planets generally have larger H? Why?